

ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ88-836

# **SPACING OF RAISED REFLECTIVE PAVEMENT MARKERS**

## **State of the Art**

### **Final Report**

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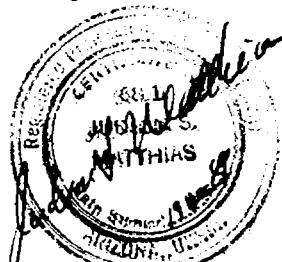
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In cooperation with  
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Federal Highway Administration

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16. Abstract  Based on available literature and a survey of state highway agencies, the spacing of raised reflectorized pavement markers (RRPM) were reviewed. The District of Columbia and the Commonwealth of Puerto Rico were also included in the survey. This review found that there is variation in the spacing of RRPM use. Policies varied concerning use based on volume, artificial lighting conditions, accident rates and type of road. A few states do not use RRPM and cite snow removal as the reason. Most states use RRPM and consider them to be very effective in traffic control and accident reduction. Several cost analyses were reviewed and these studies concluded that RRPM are cost effective in accident reductions. Recommendations for further research are included.					
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# SI\* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
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### LENGTH

in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

### AREA

in <sup>2</sup>	square inches	645.2	millimetres squared	mm <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	metres squared	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.836	metres squared	m <sup>2</sup>
ac	acres	0.405	hectares	ha
mi <sup>2</sup>	square miles	2.59	kilometres squared	km <sup>2</sup>

### VOLUME

fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft <sup>3</sup>	cubic feet	0.028	metres cubed	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	metres cubed	m <sup>3</sup>

NOTE: Volumes greater than 1000 L shall be shown in m<sup>3</sup>.

### MASS

oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

### TEMPERATURE (exact)

°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C
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## APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
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### LENGTH

mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

### AREA

mm <sup>2</sup>	millimetres squared	0.0016	square inches	in <sup>2</sup>
m <sup>2</sup>	metres squared	10.764	square feet	ft <sup>2</sup>
ha	hectares	2.47	acres	ac
km <sup>2</sup>	kilometres squared	0.386	square miles	mi <sup>2</sup>

### VOLUME

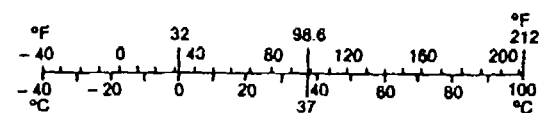
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m <sup>3</sup>	metres cubed	35.315	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	metres cubed	1.308	cubic yards	yd <sup>3</sup>

### MASS

g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T

### TEMPERATURE (exact)

°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
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\* SI is the symbol for the International System of Measurement

(Revised April 1989)

## TABLE OF CONTENTS

	<i>Page</i>
Introduction .....	1
Objectives .....	3
Work Plan .....	3
Literature Review .....	4
Survey Results .....	5
Spacing Criteria.....	6
General Policy.....	9
Recommendations for Further Study .....	16
References .....	17
Appendix A.....	20
Appendix B.....	28
Appendix C.....	32
Appendix D.....	59

## INTRODUCTION

Raised reflective pavement markers (RRPM's) are highly durable devices which provide day and night visibility under adverse weather conditions. Figure 1 shows the types recommended by ADOT Traffic Engineering. They are typical of the types used across the country.

RRPM's came into use prior to the 1970's when interest in added pavement delineation was examined as a safety feature. During the 1970's some attempts were made to evaluate the effectiveness of RRPM's.

RRPM use is as a supplement to the painted stripes on pavements. In some applications they are used in place of traditional painted stripes. They are reflectorized; that is, they reflect the light from a vehicle's headlights back towards the driver's eye and appear as a bright-colored dot of light. RRPM's provide a clear, definitive outline of the pavement markings even during poor visibility conditions such as rain, fog and darkness. RRPM's protrude through the film of water on the pavement and break the mirror-like surface of the wet pavement. Attempts have been made to use glass beads in the pavement stripe paint in an effort to provide reflectivity. These attempts were successful but only under dry roadway conditions. When the pavements were wet, the reflectivity disappeared along with the regular paint as far as the motorist was able to see. Another concern is that at night and during adverse weather conditions construction joints that are not coincident with the highway markings tend to be more visible than the pavement markings. This can be deceptive and may give incorrect information to motorists.

For daytime and nighttime conditions, the vibration and sound caused as a vehicle crosses or runs along the line of markers creates a tactile and auditory warning, as well as a visual warning. This can be expected to alert a motorist who has inadvertently crossed the roadway center line. This would apply during the daytime as well as at night or during inclement weather. Then RRPM's can be an effective tool for alerting inattentive, fatigued drivers as well as those under the influence of alcohol or other drugs.

The effectiveness, cost, and durability of RRPM's are of interest and concern. The use of RRPM's on any significant portion of Arizona's highways involves added costs for installation and maintenance. If RRPM's can decrease accidents and do so efficiently, then they can be an effective safety and control device. Uniform standards for application and use for various types of locations should be developed and applied across the state system.

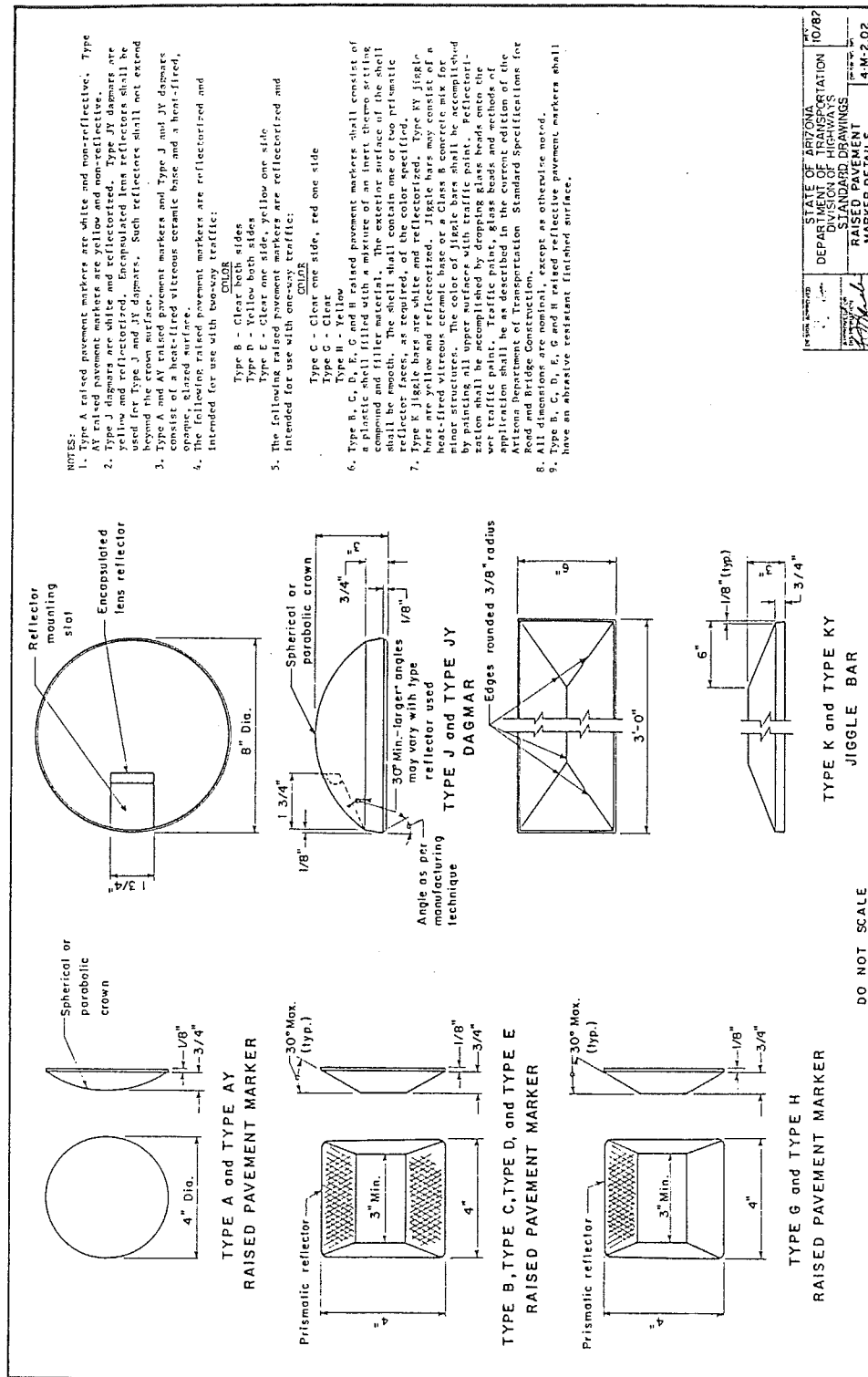


Figure 1: Raised Pavement Marker Detail

## **RESEARCH OBJECTIVES**

The objective of this research is to prepare a state-of-the-art report identifying current practice and experience with various spacing patterns used with RRPM's. A part of this objective is to develop a work plan for any recommended research identified as part of this study.

## **WORK PLAN**

In order to accomplish the objectives, the following tasks were performed:

1. A literature review was done utilizing the TRIS system to identify the relevant documents.
2. A survey of the practices and policies of the states was prepared and sent. A copy of the survey is shown in the appendices.
3. The survey results were evaluated and summarized. The various spacings and policies for use are listed by state. Thirty-nine responses were received from the states, including the District of Columbia and the Commonwealth of Puerto Rico. The Federal Highway Administration (FHWA) also provided valuable information.
4. Provide recommendations on the scope and extent of further studies if deemed warranted, based on the analysis of the data.
5. Develop a detailed work plan for any recommended research and establish the anticipated project duration and estimated budget.
6. Prepare a state-of-the-art report summarizing the results of the study.

## **DESCRIPTION OF RAISED REFLECTORIZED PAVEMENT MARKERS**

RRPM's are of two basic types: the standard raised type, and the "snow-plowable type," which are normally set in grooves in the pavement and therefore protrude a lesser distance above the pavement than the standard type. Some jurisdictions use completely recessed types; the RRPM does not protrude above the pavement surface but is flush with the surface. The recessed type of installation is thought to be a maintenance problem because dirt, water, etc., may fill the depression or groove and cause a loss of reflectivity. This has not been found to be a significant problem. The tire action of the marker causes them to be self cleaning; the rolling tire removes any debris.

## LITERATURE REVIEW

An extensive literature review indicates widespread use and acceptance of RRPM's as effective marking devices under all weather conditions and during the hours of darkness. They are used with the traditional pavement striping procedures and policies as well as being used as the only striping markings. There is extensive use as temporary pavement markings during construction even in states where they are not used because of the snow plowing needs. The references are listed as well as the replies to the survey.

Two major concerns are cost and effectiveness of RRPM's. Several studies have addressed the accident reduction experienced after installation of RRPM's, and the results indicate that RRPM's are effective in reducing run-off-the-road and head-on collisions. This accident reduction is achieved under all conditions of weather. Most states have incorporated volume or ADT (average daily traffic) criteria as well as accident rates in their RRPM policies.

The responses to the survey show general support and agreement that RRPM's, whether snow-plowable or standard, are a valuable safety feature for use on major highways and streets. Although precise agreement on spacing is not evident, the MUTCD has recently (March, 1986) issued spacing criteria that are now the national standard. The survey summary tables indicate a great deal of basic agreement on spacing and general conditions for use of RRPM's.

Several studies that address the cost and maintenance problems were found and utilized in this study. A study conducted by the state of Maryland found that 98% of RRPM's installed on a rural highway with an ADT of 12,900 vpd were in excellent condition after two years of use. Another study done in Georgia found that 81.7% remained in service after 4.9 years of use. Of particular interest in this study is that the recessed RRPM's (snow-plowable) have a significantly better survival rate than the raised RRPM's. Both studies found that there is no maintenance required for the first two years. The recessed type did not require any cleaning as it was found that traffic action actually caused the removal of dirt, water, and debris from the grooves so that reflectivity was not adversely affected.

An Arizona study found a significant accident reduction in a before and after study conducted in 1988. Of interest is that Federal Highway Administration (FHWA) sent a copy of this report to ASU as part of their response to a request for information regarding the effectiveness of RRPM's in accident reduction. Other studies from other states also corroborate the Arizona findings of significant accident reductions after the installation of RRPM's. In general, the responding agencies consider RRPM's to be very effective in regards to safety. There is little more discussion in the literature as to the safety advantages gained by use of the RRPM's. They may now be considered to be state-of-the-art insofar as safety is concerned. It can be anticipated that

RRPM use or non-use will be included in future litigation proceedings since their use is widespread nationally. The safety effects have been well documented and are available to anyone.

The MUTCD has incorporated criteria for use of RRPM's in sections 3A-10, 3B-14, 3B-14, and 3B-16 in revision no. 4, dated 1986. The Traffic Control Devices handbook (TCD) in section 3E-1 and on figures 3-21 through 3-30 has established specific spacing and placement arrangements. The sections cited are shown in the appendices.

## **SURVEY RESULTS**

The tables shown below indicate the spacings and placement reported by the responding agencies. They indicated that there is a great deal of general agreement as to spacing and the use of RRPM's. The states (8) that indicated no use gave snow conditions as the major reason. However, four of these states use RRPM's during construction work. Almost all users have established ADT, geometric, lighting, and/or accident criteria as the basis for installation of RRPM's. It can be concluded that these agencies consider RRPM's to be cost-effective devices based on their ADT, geometric, and other criteria. Arizona's analysis indicates a benefit-cost ratio of at least 78:1 based on the cost of fatal, injury, and property damage accidents reduced after installation of RRPM's. This benefit-cost ratio does not include any value associated with possible litigation.

It should be recognized that the use of RRPM's has become widespread nationally and that failure to use them could be construed to be poor engineering or negligence. There are many studies that indicate significant safety benefits from the use of RRPM's under all weather conditions.

**Table 1. SPACING CRITERIA**

Intersections							
80' c/c	40' c/c	20' c/c-24' c/c	10' c/c	80' c/c	Exit and Entrance Ramps		
40' c/c	20' c/c-25' c/c	10' c/c					
States	States	States	States	States	States	States	States
KY (on lane lines), FHWA (while leaving intersections in turn lane), NC (on white skip between through lanes) <u>2 states &amp; FHWA</u>	MS, GA, SC, IN, KY, C.W. of VA, IL, DC, FHWA (while leaving & approaching two lane), NC, (on double yellow, on white skips between turn lanes and a through lane) <u>9 states and FHWA</u>	GA, CA, NB, OR, OK, HI, FL <u>7 states</u>	WA <u>1 State</u>	MS (rural), IL (along the main line) <u>2 states</u>	MS (urban), GA, IN, CT, IL (at the gore), FL, NC (on white mini skip) <u>7 states</u>	MD, GA (on construction zone), SC, CA, TX, NM, KY, HI, C.W. of VA, WI, UT, IL (at the edge), FHWA, DC, MI, NC (on white gore line) <u>15 states &amp; FHWA</u>	AR <u>1 state</u>

**Table 1. SPACING CRITERIA (Con't)**

Curved Section Spacing			Tangent Spacing			No Passing Zone		
80' c/c	40' c/c	20' c/c	80' c/c	40' c/c-(48' c/c)	20' c/c	80' c/c	40' c/c-50' c/c	20' c/c-25' c/c
States	States	States	States	States	States	States	States	States
GA (curve less than 3°), C.W. of VA (<4°), AR (rural), WA (≥ 5000' radius), <b>Total : 4</b>	GA (curve between 3°-6°), MD, MS, SC, NM, OR, IN C.W. of VA (≥ 4°), AR (urban), IL, WA (≥ 5000' radius), FHWA (≥ 6°), FL, NC NY <b>15 states (incl. FHWA)</b>	GA (curve above 6°), IN (degree of curvature high), DE (curve 6° or more), FL (high accident curve), NC (on double yellow centre line) <b>5 states</b>	MD, MS (Rural), TX (in lane lines), NB (rural), IN, KY, C.W. of VA (w/skip line), AR (rural), IL, WA, FHWA (w/white stripe system), NC, NY <b>12 states and FHWA</b>	IA (Const. zone) MS (urban), SC, SD (for broken lines), CA, TX (for mult. undiv. H/W in centre lines), NM, NB (urban) HI, C.W. of VA (centreline of 5t lane), AR (urban), WA (along double yellow solid stripes), FHWA (w lane, 2 way; multi lane w/stripe), DC, DE (to the side of stripe supplemented) FL. <b>15 states and FHWA</b>	HI (within yellow stripe in median) FHWA multi-lane 2 way), <b>1 state &amp; FHWA</b>	GA, AR (rural), IL, NC <b>4 states</b>	SC, OR (rural), IN, KY, C.W. of VA, WI, (50' c/c), AR (urban), FHWA (w/stripe system), FL. <b>8 states and FHWA</b>	CA, TX, HI, ID, FHWA, 5 states <b>5 states</b>

**Table 1. SPACING CRITERIA (Con't)**

<div> <div>80' c/c</div> <div> <div>Passing Zone</div> <div>40' c/c</div> <div>20' c/c</div> </div> </div>			<div> <div>120' c/c</div> <div> <div>Divided Roadways</div> <div>80' c/c</div> <div>40' c/c-48' c/c</div> </div> </div>			<div> <div>80' c/c</div> <div> <div>Two way Median Turn Lanes</div> <div>40' c/c</div> <div>20' c/c or 24' c/c</div> </div> </div>		
States	States	States	States	States	States	States	States	States
GA, TX, IN, C.W. of VA, AR (rural), IL, WA, NC <u>7 states</u>	SC, CA, OR (rural), HI, AR, (urban), ID (50' c/c), FHWA (w/stripe system), FL <u>7 states and FHWA</u>		CT (to supplement <u>1 state</u> )	MD (on tangent), GA, TX, IN, C.W. of VA, CT, AR (rural), IL, NC <u>10 states</u>	MD (on curved), CA, KY, (along concrete median barrier), HI, AR (urban), DC, FL <u>7 states</u>	MD (on tangent), GA, TX, WA, NC <u>5 states</u>	MD (curve), IN, WI (50'), AR, IL, FHWA, DC, FL <u>7 states and FHWA</u>	CA, ID <u>Two states</u>

# General Policy

## STATE

## POLICY

1) *Kentucky*

- a) Use V metal snow-plowable pavement markers (not on bridge decks and local roads).
- b) No PM on collector in local malls in Urban Area.
- c) No PM on local roads in Rural Area.
- d) No PM on collectors if ADT  $\geq$  300.
- e) PM marks in all construction zones.

2) *Delaware*

- a) No RPM or combination RPM/Stripe for Right edge line markings except for delineation e.g. ramps, gores, bifurcations narrow bridges, detours, or at spot hazard.

***Temporary RRPM's***

- a) Not used during winter because of damage due to snow plow blades.
- b) White RRPM's shall not be used for edgelines.

3) *District of Columbia*

- a) Wholly urban area.
- b) Provides RRPM's on Interstate, divided and two-way median turn lanes.

4) *South Carolina*

- a) Only installed on interstate routes and primary routes.
- b) Primary routes must have ADT  $\geq$  10,000, multilane facility and thermoplastic pavement markings.

5) *Mississippi*

- a) Uses RRPM's on all Interstate Highways and other multilane, divided or individual highways.
- b) No RRPM's on two-lane facilities.

# General Policy, Cont.

## STATE

## POLICY

- |                            |   |
|----------------------------|---|
| 6) <i>Iowa</i>             | a) Only in temporary construction zone.   |
| 7) <i>New Hampshire</i>    | a) Does not use RRPM's.<br>b) Only in seasonal construction zone.   |
| 8) <i>Georgia</i>          | a) Uses on Interstate or Interstate type highways under construction except projects consist ing primarily of asphalt resurfacing items.  |
| 9) <i>Washington State</i> | Not available.  |
| 10) <i>Idaho</i>           | a) Smallest size is used for lane channelization or to delineate traffic islands with speed $\leq 30$ mph.<br>b) On concrete surfaces installed adjacent to the joints.   |
| 11) <i>Maryland</i>        | <b>Recommendations</b><br>a) Use of RRPM's in longitudinal joint problem area on high speed freeways in area of high accident frequency.<br>b) Should be installed in advance of curved highway sections or other problem areas to facilitate the change in pavement marking lines for motorists. |
| 12) <i>Illinois</i>        | a) Uses RRPM's on high accident locations.<br>b) Rural uncurbed left-turn lanes.<br>c) Rural lane-reduction transitions.<br>d) Expressway & freeway gores & bifurcations.<br>e) Two way left turn lanes.<br>f) Multilane undivided highways.  |

# General Policy, Cont.

## STATE

## POLICY

- |                        |  |
|------------------------|--|
|                        | g) Rural two-lane, two-way highway, ADT $\geq$ 15,000.   |
|                        | h) Multilane divided highways, ADT $\geq$ 2500.  |
|                        | i) One-way streets, ADT $\geq$ 7500.   |
|                        | j) Rural horizontal curve marked 10 mph or more below the posted speed limit.  |
| 13) <i>Utah</i>        | a) Recently adopted on all unlit exit ramps, ADT > 100.  |
|                        | b) Plan to use in areas of high weave sections, susceptible to fog and curvilinear alignment.  |
| 14) <i>Arkansas</i>    | Not available.   |
| 15) <i>Colorado</i>    | a) Uses to delineate lane drops and cross-over operations on some Interstate construction zone projects.                               |
| 16) <i>Connecticut</i> | a) Uses snow-plowable RRPM's and concentrated Uses on non-illuminated expressways.   |
| 17) <i>Wisconsin</i>   | a) Uses plowable RRPM's.   |
|                        | b) Uses on rural highway, ADT > 6000.  |
|                        | c) Urban streets, ADT > 15000, where continuous street lighting is not provided.   |
|                        | d) Restricted to areas where the pavement is structurally unsound or where resurfacing is anticipated within five years.               |
|                        | e) Uses on horizontal curves that are not compliant with design standards and speed is reduced by 10 mph or more from the legal speed. |
|                        | f) On combination of severe horizontal curves and vertical curves.   |

## General Policy, Cont.

### STATE

### POLICY

- |                                     |  |
|-------------------------------------|--|
| 18) <i>California</i>               | a) Uses on two lane streets, highways, multilane streets and highways.   |
| 19) <i>Commonwealth of Virginia</i> | <p>a) Spacing of RRPM's are same as for recessed pavement markings</p> <p>b) Same spacing, both rural and urban areas</p> <p>c) Normally, Virginia uses recessed markers instead of raised or snow-plowable RRPM's, because of cost &amp; damage of RRPM's due to snow plows.</p>  |
| 20) <i>Hawaii</i>                   | a) Not available. Pavement markings are based on MUTCD.  |
| 21) <i>Montana</i>                  | a) Montana does not use RRPM's   |
| 22) <i>Oklahoma</i>                 | a) Uses for increased visibility and traffic control.  |
| 23) <i>West Virginia</i>            | <p>a) Follows the practices of Traffic Control Device Handbook.</p> <p>b) Uses RRPM's on freeway when ADT (two-way) <math>\geq 10,000</math>, on a bituminous concrete pavement surface.</p>   |
| 24) <i>New Mexico</i>               | Not any particular policy available.   |
| 25) <i>Indiana</i>                  | <p>a) Uses only snow-plowable RRPM's.</p> <p>b) Uses on locations of fog, smoke and in areas of low roadway illumination.</p> <p>c) Does not use on area scheduled for resurfacing during next four year period.</p> <p>d) Uses on ADT <math>\geq 2500</math> for two lane roads. Uses on ADT <math>\geq 6000</math> for four lane roads</p> <p>e) Generally does not use RRPM's for edge line or gore markings.</p> |

# General Policy, Cont.

## STATE

## POLICY

- |                           |   |
|---------------------------|---|
| 26) <i>Alaska</i>         | a) Generally does not use RRPM's.   |
| 27) <i>Oregon</i>         | a) Uses RRPM's for lane line visibility under wet pavement and poor visibility weather conditions.  |
| 28) <i>Nebraska</i>       | a) RRPM's are plowable type.<br>b) Uses limited due to cost.  |
| 29) <i>Maine</i>          | a) Experimental basis.<br>b) Poor experience of RRPM's due to snow removal efforts.   |
| 30) <i>Texas</i>          | a) Spacing of RRPM's are reduced in Urban Areas or in areas where alignment changes.  |
| 31) <i>Vermont</i>        | a) Does not use RRPM's for permanent delineation.<br>b) Temp. RRPM's are used 20' C to C. All in yellow color and reflect in both directions of Travel. |
| 32) <i>Missouri</i>       | a) Recently installed in two test areas. No data available.   |
| 33) <i>South Dakota</i>   | a) Not available.   |
| 34) <i>FHWA</i>           | a) Based on standards incorporated into the Manual on Uniform Traffic Control devices by Revision No. 4, dated March, 1986.                             |
| 35) <i>North Carolina</i> | a) Uses snow-plowable types of pavement markers on permanent installations.<br>b) Restricts the use of RRPM's on temp. installations.                   |

## General Policy, Cont.

### *STATE*

### *POLICY*

36) *Florida*

- a) RRPM's are used on centerlines, lane lines, in the case of exit and entrance ramps for edge lines.
- b) Generally spacing = 40', except in case of high accident rate, it is 20'.

37) *Michigan*

- a) Only experimental to-date.

38) *North Dakota*

- a) Does not use permanent RRPM's.

39) *Commonwealth  
of  
Puerto Rico*

- a) Two-way roadways w/o median barriers. Also in areas subject to fog.

The cost of RRPM's is a concern. The current data indicate that RRPM's cost about \$800 per mile based on 40-foot spacing and a divided highway (double center line). Using that figure and considering that the state highway system mileage to be 6,149 miles, it is possible to estimate the annual cost of installing RRPM's on the state system. Analysis of the data show that most states do not install RRPM's if pavement overlay or replacement is to be done within five years or less. This would likely reduce the mileage available for RRPM's to approximately 4,800 miles. Assuming that an RRPM will last for four years, which is a reasonable assumption based on the reported experience in other states, the cost per mile per year would be \$200. The annual cost per year to ADOT would be:

$$4800 \text{ miles} * \$200 = \$960,000.$$

This is not excessive if it is considered that the accident costs reduced on a 30-mile test section amounted to \$444,000 in one year and that the annual cost to ADOT was \$5,643. The ADOT cost was based on a three-year life and an interest rate of 10%. No interest rate was used to estimate the annual cost for the state cost \$960,000, the value of \$200 per year per mile is adequate for illustrative purposes. These cost figures are similar to those reported by other states. An additional factor is that much of the state system is two-lane, two-way; the cost for this mileage would be less than the \$800 per mile found for divided highways which are normally of four or more lanes.

## **RECOMMENDATIONS**

1. ADOT should adopt a policy for the installation of RRPM's on the state system to be in conformance with national practice and criteria as soon as possible. Criteria should specify the minimum ADT. Geometric criteria based on degree of curvature should also be developed. An accident criteria based on rates and exposure should be developed. The length of a section of RRPM's should be specified; short sections are undesirable and confusing.

Spacing criteria should be in conformance with the MUTCD.

2. There should be a continuing evaluation effort to establish more precise accident reduction data. Several years of before and after data are needed for a statistically valid sample due to the random nature of accidents. Such a study would require three years of after-volume and accident data to be compared with three years' prior volume and accident data. Analysis would determine accident rates for each period by type of accident, type of road, time of day, and speed. Types of accidents susceptible to reduction by RRPM's would be determined. Test sections would be selected to include various combinations of pavement type, number of lanes, posted speeds or 85th percent, presence or absence of artificial lighting, intersection area, and traffic control, geometrics, and rural/urban areas.

This study would take three years to complete. The level of effort would require approximately six man months for the principal investigator over the period and three man months for a research assistant over the entire period. The total cost would be approximately \$75,000 for the entire project. The project would document the costs of installation and maintenance, as well as the accident reduction with the appropriate costs.

3. An initial project to develop specific criteria for the use and placement of RRPM's could be done through the man-year release program in four months and would require approximately one man-month of effort.

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**APPENDIX A**

***BEFORE AND AFTER STUDY***

***S.R. 85 MILEPOST 120.26-150.50***

**ADOT**

**JUNE 1988**

## PURPOSE

At the request of the Assistant Traffic Engineer for Traffic Design Services, a before and after evaluation of the installation of raised pavement markers was conducted. The installation of centerline reflectorized raised pavement markers (RPM's) and thermoplastic striping, along with a pavement mill and replacement, on S.R. 85 was completed under Project F-023-1(13) on February 13, 1987 from milepost 120.26 through milepost 150.50.

## PHYSICAL FEATURES

State Route 85 is a principal arterial highway which connects the Phoenix metropolitan area to the Mexican border at Lukeville. Along the 30.24-mile study section from Gila Bend to Buckeye, the roadway is forty feet wide with a twelve-foot travel lane and an eight-foot paved shoulder for each direction of traffic. The southernmost one mile of the study section (milepost 120.26 to 121.26) is located within Gila Bend and provides two twelve-foot travel lanes for each direction along with eight-foot shoulders.

There is a four-degree horizontal curve at the southern end of the study section in Gila Bend. All the other horizontal curves along the study section are 0°-15' or 0°-30' curves. The vertical grade is level on the average along the length of the study section with the steepest grade of +2.00% occurring at milepost 145.9 for southbound traffic.

## TRAFFIC CHARACTERISTICS

The study section runs north-south between Gila Bend and Buckeye. Average daily traffic volumes recorded in 1984, 1985, and 1986 were 7900, 7100, and 8500 vehicles per day, respectively. A relatively high percentage of commercial vehicles (25%) is estimated to travel this roadway section. It provides the most direct route between Interstate-10 on the west side of the Phoenix metropolitan area and Interstate-8 to Yuma and San Diego. Thirteen percent of all vehicles are estimated to be non-Arizona vehicles.

The land adjacent to the roadway section is not developed. The terrain is level to rolling and is covered with desert brush. The only side friction is from a service station and restaurant located near the center of the section and approximately fifteen junctions and intersections along the study section.

The speed limit is posted for 55 mph through most of the study section from milepost 121.25 to milepost 150.50. The posted speed limit in Gila Bend is 45 mph from milepost 120.60 to milepost 121.25. From milepost 120.26 to milepost 120.60 the speed limit is posted for 35 mph.

## ACCIDENT ANALYSIS

Accidents were studied during periods before and after the installation of the raised pavement markers. The installation of the markers from milepost 120.26 to milepost 150.50, along with a pavement mill and replacement, was started on October 23, 1986 and completed on February 13, 1987. Accident data for the following periods was available for the study:

Before: February 14, 1985 to April 30, 1986

After: February 14, 1987 to April 30, 1988

Selected accident data for S.R. 85 from milepost 120.26 to milepost 150.50 is tabulated below:

<u>ACCIDENTS</u>	<u>BEFORE</u>	<u>AFTER</u>
Total Number	66	29
Total Rate (acc/MVM)	0.66	0.26
Total Nighttime	25	11

Traffic volumes for 1987 are not available. Therefore, the 1986 average daily volume of 8500 vehicles per day was used to calculate the accident rates for the "after" period. It is assumed that the 1987 volume will be the same, if not greater, than the 1986 volume.

Of the 66 accidents reported during the period before the improvements, thirteen involved vehicles crossing the centerline, eleven were non-contact incidents, eleven vehicles ran off the road, nine involved a vehicle defect, nine vehicles overturned, five were rear end incidents, five struck animals in the roadway, and three were angle accidents.

Of the 29 accidents reported during the period after the improvements, nine involved vehicles crossing the centerline, three were non-contact incidents, three were rear end incidents, three involved vehicle defects, three struck animals in the roadway, three vehicles overturned, two ran off the road, two were angle accidents, and one vehicle struck a vehicle parked in the emergency lane.

The total number of accidents reported along the study section decreased 56 percent after the pavement replacement and installation of the markers. Three of the reported accidents occurred on a wet pavement.

The total number of nighttime accidents also fell 56 percent from the "before" period to the "after" period.

The installation of reflectorized RPM delineation is expected to reduce the nighttime accidents involving unsafe passing and run-off-the-road accidents. Eight nighttime accidents involving vehicles crossing the centerline were reported during the period before the RPM installation, and five were reported during the period after the RPM installation:

- BEFORE:
1. 4-8-85 01:00 Run-off-road. Northbound driver was reaching down for a soda and crossed the centerline. Southbound driver avoiding northbound vehicle ran off roadway and struck a tree.
  2. 4-18-85 21:30 Sideswipe-Opposite Direction. Northbound truck crossed centerline and struck mirror of southbound truck. Hit-and-run.
  3. 5-30-85 00:30 Overturned. Northbound driver fell asleep, ran off left side of roadway, and overturned.
  4. 7-29-85 04:00 Overturned. Southbound driver fell asleep, ran off left side of roadway, and overturned.
  5. 10-6-85 23:10 Run-off-road. Northbound driver fell asleep, ran off left side of roadway, and struck a tree.
  6. 10-24-85 19:30 Unsafe Passing. Vehicle #1 northbound passed vehicle #2 and struck its fender while attempting to return to the northbound lane.
  7. 11-12-85 21:20 Unsafe Passing. Vehicle #1 southbound attempted to pass Vehicle #2 which was turning left into a rest area.
  8. 11-27-85 08:35 Unsafe Passing. A northbound vehicle overturned after trying to avoid a southbound vehicle which was overtaking another southbound vehicle.

- AFTER:
1. 6-16-87 22:45 Sideswipe-Opposite Direction. Northbound truck was passing another northbound vehicle and forced a southbound vehicle off of the road.
  2. 7-5-87 20:20 Run-off-road. Northbound vehicle was attempting to pass, lost control, and ran off of the roadway.
  3. 11-3-87 21:50 Sideswipe-Opposite Direction. Northbound driver fell asleep, crossed centerline, and struck two southbound vehicles.

4. 11-21-87 02:00 Unsafe Passing. Northbound vehicle overturned after being run off the road by a vehicle that had just passed it.
5. 12-13-87 01:51 Rear End. Northbound vehicle started to pass, returned to the northbound lane, and struck the rear of the vehicle ahead.

The most significant contributing factor in the 13 accidents was reported as unsafe passing and/or overtaking.

For daytime and nighttime conditions, the vehicle vibration and sound produced by vehicles crossing the markers creates a tactile and auditory warning as well as providing a visual warning. This would be expected to alert a driver who has inadvertently crossed the roadway centerline and should contribute to a reduction in run-off-the-road incidents by drivers who are fatigued, inattentive, or under the influence of alcohol, as well as a reduction in head-ons and sideswipes at all times of the day. During the study period before RPM installation, seven accidents occurred during daylight hours involving vehicles inadvertently crossing the centerline, while three were reported after the installation.

- BEFORE:
1. 3-23-85 15:00 Southbound driver fell asleep, ran off left side of the roadway, and struck a fence.
  2. 4-8-85 07:20 Northbound driver fell asleep, ran off left side of the roadway, and struck guardrail.
  3. 6-2-85 19:00 Southbound driver was inattentive, ran off left side of the roadway, and struck a fence.
  4. 6-9-85 05:45 Southbound driver fell asleep, crossed centerline, and struck two northbound vehicles.
  5. 6-16-85 06:45 Southbound driver fell asleep, ran off left side of the roadway, and struck a fence.
  6. 3-12-86 08:50 Southbound driver was inattentive, crossed centerline, and struck northbound vehicle head-on.
  7. 4-20-86 13:45 Southbound driver fell asleep, crossed centerline, and sideswiped a northbound vehicle (1 Fatality)

- AFTER:
1. 3-4-87 07:40 Southbound driver fell asleep and drove off left side of the roadway.
  2. 4-6-88 07:30 Northbound driver fell asleep, ran off left side of the roadway, and struck a boulder.

3. 4-8-88 16:15 Northbound vehicle pulled out to pass, saw southbound vehicle, returned to northbound lane, and forced another northbound vehicle off the road.

#### BENEFIT-TO-COST ANALYSIS

Based on the total number of accidents, the benefit-to-cost ratio is calculated to be 158 : 1.

Based on the accidents involving vehicles crossing the centerline, the benefit-to-cost ratio is calculated to be 78 : 1.

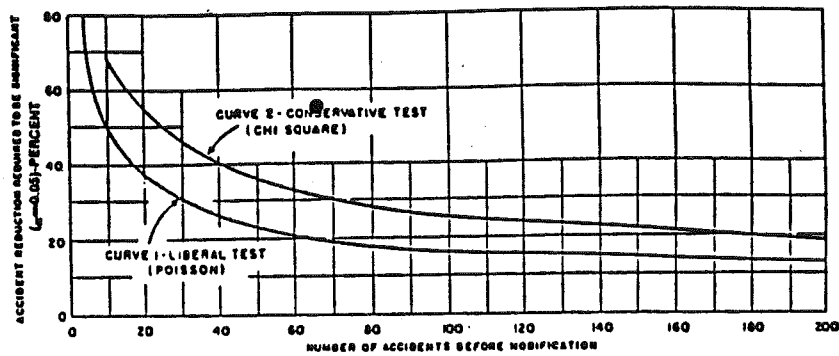
#### SUMMARY

The construction on S.R. 85 from October 23, 1986 through February 13, 1987 impacted the traffic patterns along the study section; the four months of accident data during the construction period is not comparable to other periods. The same months were selected for the "before" period and for the "after" period to eliminate any seasonal fluctuations in traffic patterns.

The accident rate along the 30.24-mile long study section decreased 56 percent after the installation of the RPM's. The total number of nighttime accidents also fell 56 percent from the "before" period to the "after" period.

The only roadway or traffic characteristic known to have changed between the "before" period and the "after" period was the pavement condition and the presence of centerline reflectorized raised pavement marker delineation. Therefore, it can be assumed that the pavement and/or delineation improvements were contributing factors in the decline of accidents.

A significance test for accident reduction is illustrated by the figure below. The two curves represent the limiting conditions for determining whether or not a significant reduction in accidents has occurred at the 95 percent confidence level. Curve 1 is based on the Poisson distribution and produces a liberal judgment as to the significance of accident reduction. Curve 2 is based on the chi-square distribution and is a more conservative judgment.



Curves of significance test for accident reduction.

The total of sixty-six accidents reported during the "before" period were reduced 56 percent during the "after" period. This falls above the conservative value of a 50 percent reduction read from the curves.

The installation of reflectorized RPM delineation is expected to reduce the nighttime accidents involving unsafe passing and run-off-the-road accidents. Eight nighttime accidents involving a vehicle crossing the centerline were reported during the period before the RPM installation, while five were reported during the period after the RPM installation.

The installation of reflectorized RPM delineation is expected to reduce daytime and nighttime accidents involving drivers inadvertently crossing the roadway centerline; the noise and vibration produced by a vehicle crossing the markers is expected to alert the driver. Before RPM installation seven accidents occurred during daylight hours involving a driver inadvertently crossing the centerline, while three were reported after the improvements were completed.

### CONCLUSIONS

The installation of centerline reflectorized raised pavement markers appears to have contributed to the 56 percent reduction in nighttime accidents along the study section. During the study period before the improvement, eight nighttime run-off-the-road accidents and accidents involving a vehicle unsafely passing were reported, while five were reported during the period after the improvement. The seven daytime accidents involving drivers who inadvertently crossed the centerline during the "before" period were reduced to three during the "after" period. Both reductions appear to be significant.

The total accident reduction of 56 percent falls above the conservative value of significance for the 95 percent level of confidence.

ARIZONA DEPARTMENT OF TRANSPORTATION  
TRAFFIC ENGINEERING SECTION  
TRAFFIC STUDIES BRANCH

Project: SR 85 (MP 120.26-150.50)

BENEFIT / COST RATIO TABULATION

BENEFITS

Acc. Type	Annual Avg.	Alt. #	Est'd. Reduct.	Total Reduct.	Unit Cost	Alt #1	Alt #2
Fatality	0.33	(1)	100%	0.33	1,239,309	\$413,062	
	0.67	(2)	100%	0.67	1,239,309		\$830,337
Injury	3.00	(1)	67%	2.00	15,700	31,400	
	7.00	(2)	43%	3.01	15,700		47,257
P.D.O.	1.67	(1)	0%	0	1857	0	
	14.33	(2)	60%	8.60	1857		15,970
Total Annual Benefits:						\$444,462	\$893,564

COSTS

Total Construction Costs:	\$14,034
Salvage Value	0
Project Life (years)	3
Interest Rate (%)	10%
Capital Recovery Factor	.4021
Annual Const. Cost = CRF X Total Const.Cost	\$5643
Cost: Total Annual	\$5643

BENEFIT - COST

Alt. #	Annual Benefit	Annual Cost	B/C Ratio
1	\$444,462	\$5643	78 : 1
2	\$893,564	\$5643	158 : 1

**APPENDIX B**

***MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES***

***MUTCD***

***SECTIONS ADDRESSING RRPM'S***

### **3A-10 Raised Pavement Markers, Reflectorized and Non-Reflectorized**

Raised pavement markers may be used as positioning guides, or to supplement, or in some cases to substitute for other types of markings. The color of raised pavement markers shall conform to the color of the marking for which they serve as a positioning guide, or for which they supplement, or substitute.

Retroflective raised pavement markers are generally preferable for most applications. Non-retroflective raised pavement markers should not be used alone, without supplemental retroflective markers, as a substitute for other types of pavement markings.

Retroreflectorized raised pavement markers normally are available in mono-directional and bi-directional configurations with white and yellow retroflective elements. Other colors, and combinations of colors, may be used for special purposes. Use should be made of the mono- and bi-directional characteristics available to maximize the information given to the motorist, to minimize wrong information and to avoid confusion resulting from visibility of markers which do not apply to the motorists.

The spacing of raised pavement markers used to supplement or substitute for other types of longitudinal markings should be chosen in relationship to the pattern of broken lines being supplemented or substituted for, using a value of "N" equal to the length of one line segment plus one line segment plus one gap.

Applications of raised pavement markers are described in Sec. 3B-14, 3B-15 and 3B-16. These applications are not intended to preclude the use of metallic markers or inserts, less than 1" high with no other coloring or retroreflectorization on the pavement when installed primarily to aid in repainting or installation of other types of markings. Such devices are not classified as raised pavement markers.

### **3B-14 Pavement Markers as Vehicle Positioning Guides with Other Longitudinal Markings**

Raised pavement markers may be used as positioning guides with other longitudinal markings, without necessarily conveying information to the motorist as to passing or lane use restrictions. In such applications, markers may be used, positioned between the two lines of a one-way or two-way no-passing zone, or in line with or immediately adjacent to a single solid or broken center line or lane lines. On concrete pavements, the raised markers should be placed to one side of longitudinal joints. A typical spacing for such applications is 2N. (See Section 3A-10 for definition of N.) Where the driver's attention should be drawn to changes in travel path, such

as sharp curves or transitions to reduce the number of lanes or shift traffic laterally, the spacing may be reduced to  $N$ , or less.

### **3B-15 Raised Pavement Markers Supplementing Other Markings**

Raised pavement markers may be used to supplement other longitudinal markings. Where double lines are to be supplemented, pairs of markers placed laterally in line with, or immediately outside of the two lines, should normally be used. When supplementing wide lines, raised pavement markers may be placed laterally adjacent to each other to simulate the width of the line.

1. Solid lines should be supplemented at a spacing no greater than " $N$ ", except left edge lines, which should be supplemented at a spacing no greater than  $N/2$ . Raised markers generally should not supplement right edge lines.

2. Broken lines should be supplemented at a spacing no greater than  $2N$ , except those identifying reversible lanes, which should be supplemented at a spacing no greater than " $N$ ".

3. Dotted lines should be supplemented with spacing appropriate for the application. Typical spacing for pavement markings through at-grade intersections is one raised marker for each short line segment or "dot". For edge line extensions through freeway interchanges, the typical edge line spacing of  $N/2$ , may be used.

Raised pavement markers may also be used to supplement other markings for channelizing islands or approaches to obstructions. Positioning and spacing of the markers in such cases must be determined by engineering judgment.

### **3B-16 Substituting for Pavement Markings**

Retroflective raised pavement markers, or non-retroflective raised pavement markers supplemented by retroflective markers, may be substituted for markings of other types.

The pattern of the raised markers should simulate the pattern of the markings for which they are substituted.

The normal spacing of raised pavement markers, when substituting for painted markers, should be chosen in relationship to the standard length of the broken line segment.

Broken line segments may be substituted by a group of four or five markers equally spaced at approximately  $\frac{N}{12}$  feet, or at approximately the third point of the line segment if  $N$  is other than 40 feet, with at least one of every group of markers retroreflective.

Solid lines may be substituted for at a spacing of approximately  $\frac{N}{8}$  feet, with retroreflective units at a spacing no greater than  $\frac{N}{2}$ .

Dotted lines shall be substituted for at a spacing of approximately  $\frac{N}{8}$  feet, but with not less than one raised pavement marker per dotted line. At least one raised marker every N feet shall be retroreflective.

When substituting for wide lines, raised pavement markers may be placed laterally adjacent to simulate the width of the line.

**APPENDIX C**

***SECTIONS AND FIGURES***

***FROM THE TCD HANDBOOK THAT ADDRESS  
RRPM'S AND THE SPECIFIC APPLICATION  
CRITERIA***

### **3E. SPECIAL CONSIDERATIONS**

The MUTCD is quite clear in prescribing and illustrating guidelines for the application of conventional markings, pavement word messages and symbols, curb markings, etc. There are two topics of concern to marking systems that have not been precisely defined in the MUTCD: application patterns of raised markers and new techniques for establishing no passing zones. Primarily, these items have been the subject of investigation and evaluation for incorporation into the MUTCD as a rule change or request for interpretation.

The following section presents a general summary discussion of the suggested guidelines currently under development. Because these guidelines have not as yet been formally adopted, the up-to-date status and specific applications should be confirmed by the using agency.

#### **3E-1 Configurations for Raised Markers Usage**

The MUTCD presently provides illustrations and application guidelines for the configuration of marking systems using paint, thermoplastic, and other durable markings. While it states that "...Individual unit markers, generally less than 1 inch in height, may be used for pavement marking purposes" it does not show possible configurations or patterns for the use of these devices.













An effort is underway to develop national standards for the placement of pavement markers when they are used alone or in combination with other on-the-road striping. Figures 3-21 through 3-30 are intended as general guidelines only and are subject to change when efforts have been completed to adopt national standards. Figures 3-21, 3-22, and 3-23 present the basic patterns and spacing for centerlines, lane lines and other solid lines currently in general use.

Figures 3-24 through 3-30 are based on a report prepared by the Amerace Corporation and modified by the FHWA. Since policy among agencies may differ, the patterns shown are generally dimensionless. In these figures, "Normal Spacing, N" represents the combined length of the stripe and gap. Drawing dimensions can be adjusted to meet individual agency requirements.

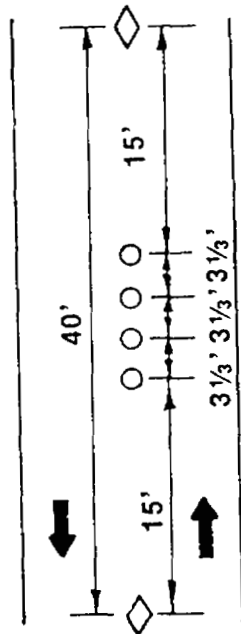
The marker pattern for construction zones that appears to provide the driver with the best visual perception on tangent sections when markers are used to supplement painted lines consists of a spacing of 40-foot. That is, a reflective RPM is placed midway between each 10-foot paint stripe as shown in Figure 3-30, a and b.

A spacing of 20 feet is recommended for curves since it provides the driver with twice the number of markers as shown in figure 3-30, d and e. It also recognizes the premise that the loss rate on curves will be higher, leaving voids in the pattern.

## SYMBOLS

	Yellow Stripe
	White Stripe
	Two-Way Yellow RPM
	Two-Way White RPM
	One-Way Yellow RPM
	One-Way White RPM
	Non-Refl. Yellow RPM
	Non-Refl. White RPM
	White/Red RPM
	Yellow/Red RPM
N	Normal Spacing
	Directional Arrow
	Pavement Arrow

Symbols to be Used with Figures 3-21 through 3-30



a. RPM System (2-lane, 2-way)

b. Combination RPM/Stripe

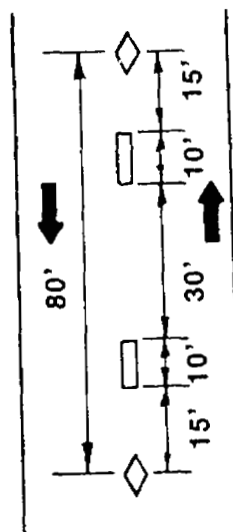
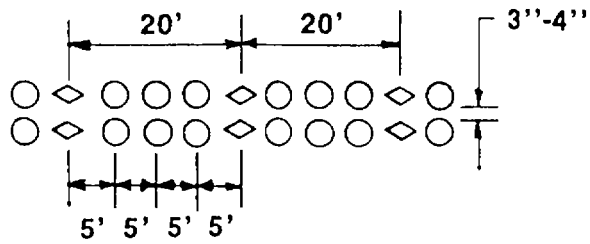


Figure 3-21 Centerline Patterns

c. RPM System (multilane, 2-way)



d. Combination RPM/Stripe System (multilane, 2-way)

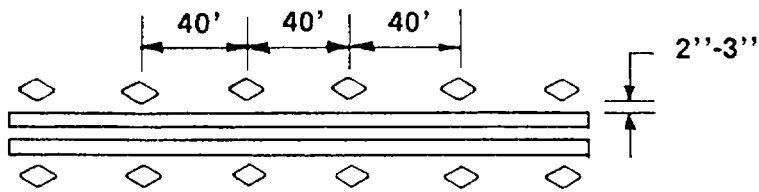
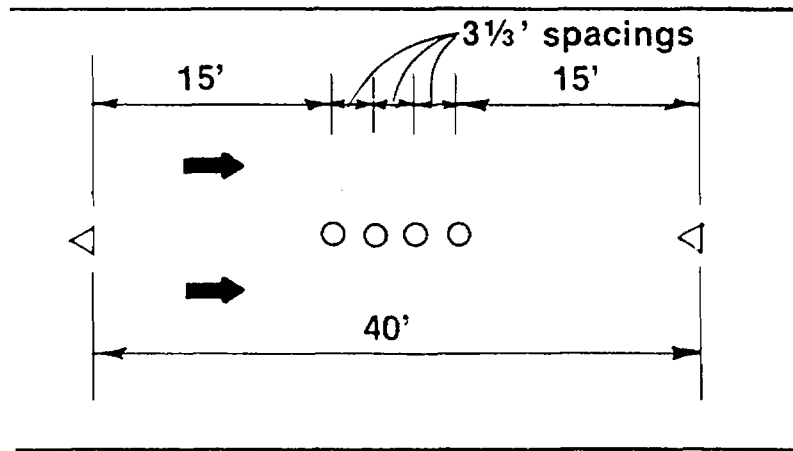


Figure 3-21 Centerline Patterns (Con't)



a. RPM System

b. Combination RPM/Stripe System

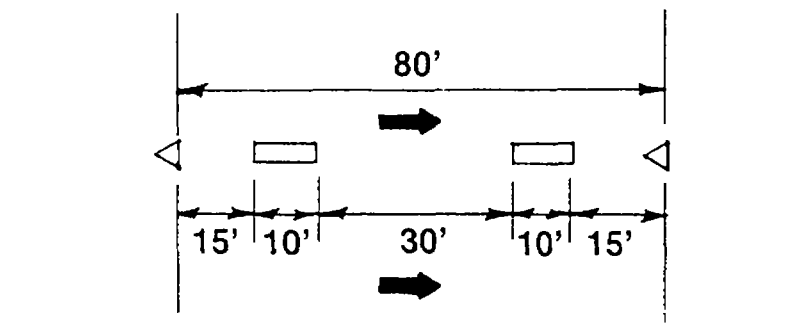


Figure 3-22 Lane Line Patterns

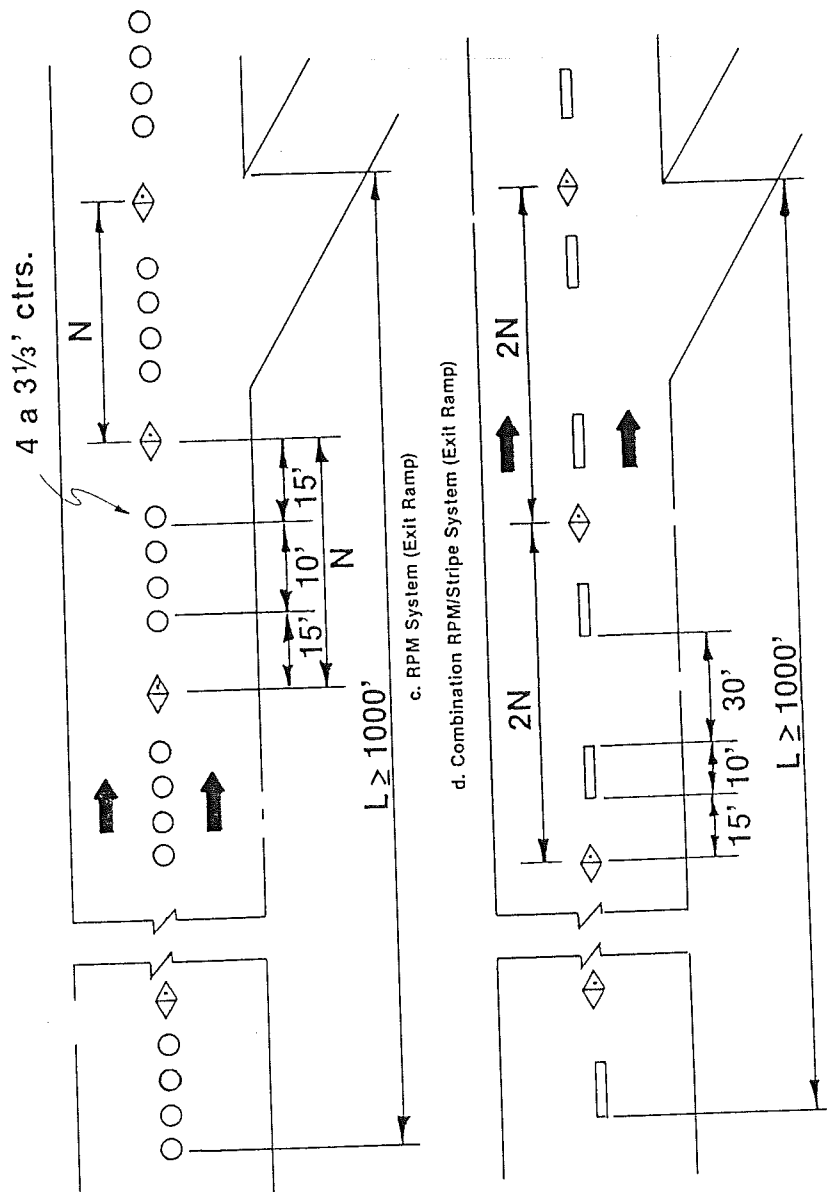
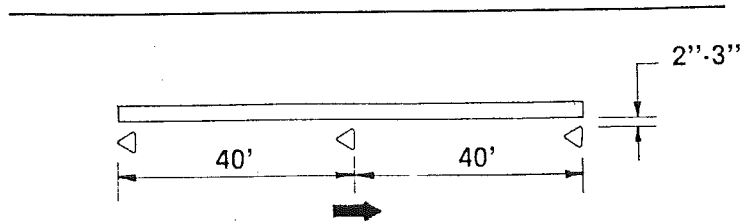
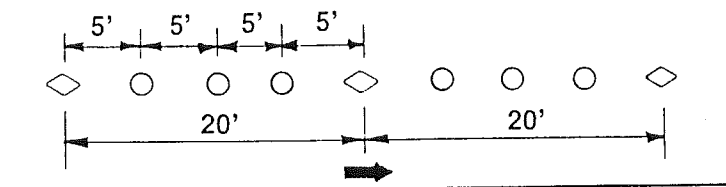


Figure 3-22 Lane Line Patterns ( Con't)



a. Combination RPM/Stripe System for Left Edgeline (RPM's are not recommended for Right Edgelines)

b. RPM System for No-Passing Line



c. Combination RPM/Stripe System for No-Passing Line

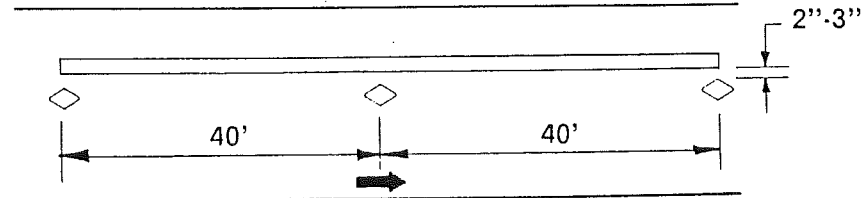
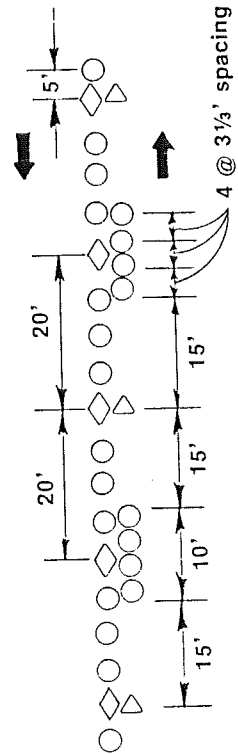


Figure 3-23 Marking Patterns for Solid Lines



d. RPM for No-Passing/Passing Zones

e. Combination RPM/Stripe System for No-Passing/Passing Zones

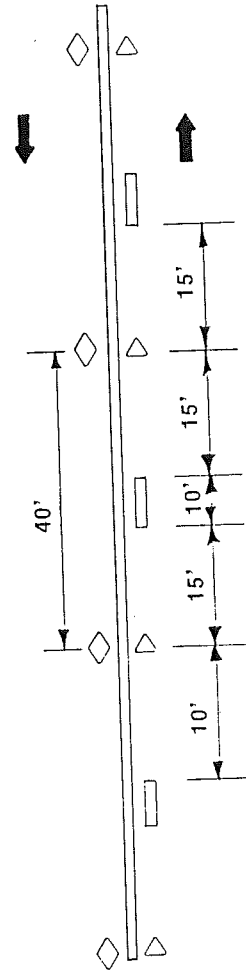
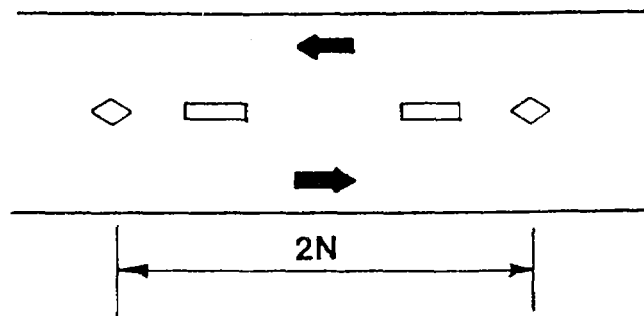
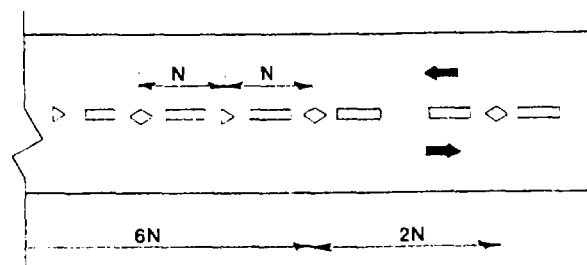
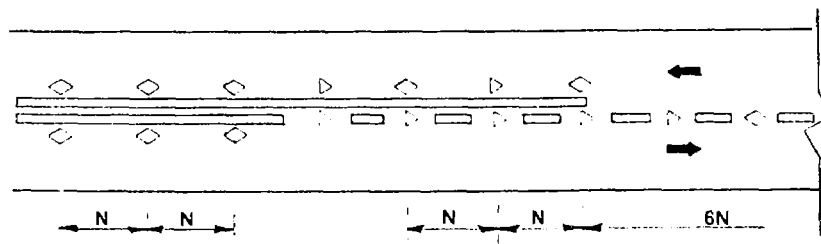


Figure 3-23 Marking Patterns for Solid Lines (Cont'd)

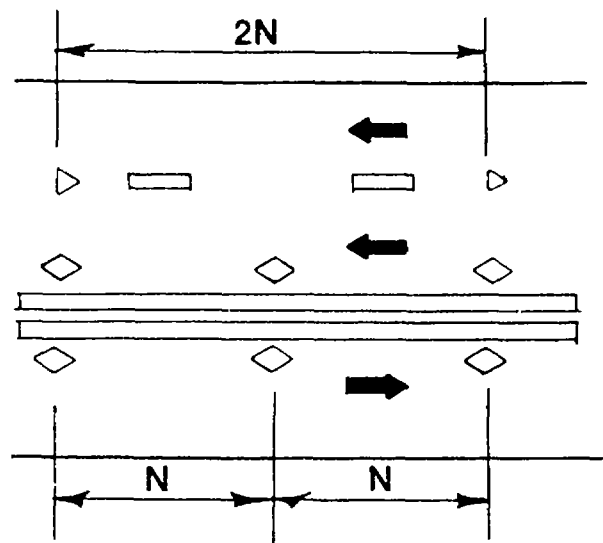


a. Two Lanes

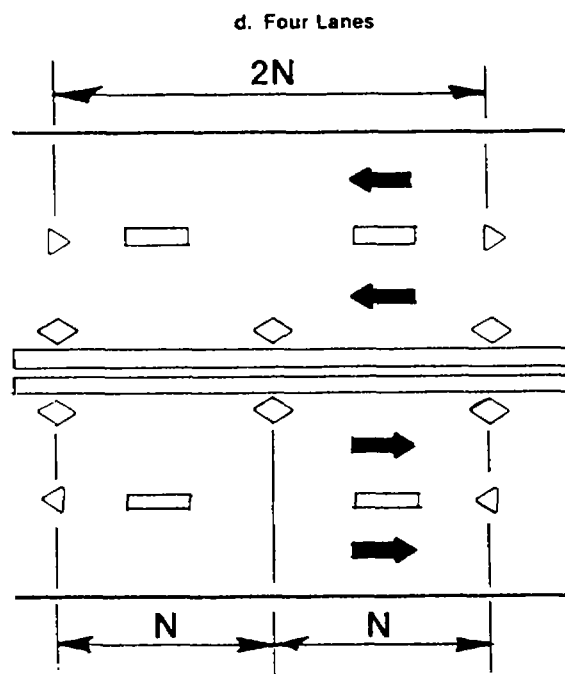


b. No-Passing Zones (Two Lanes)

Figure 3-24 Marking Patterns for Two-Way Roads



c. Three Lanes



d. Four Lanes

Figure 3-24 Marking Patterns for Two-Way Roads (Con't)

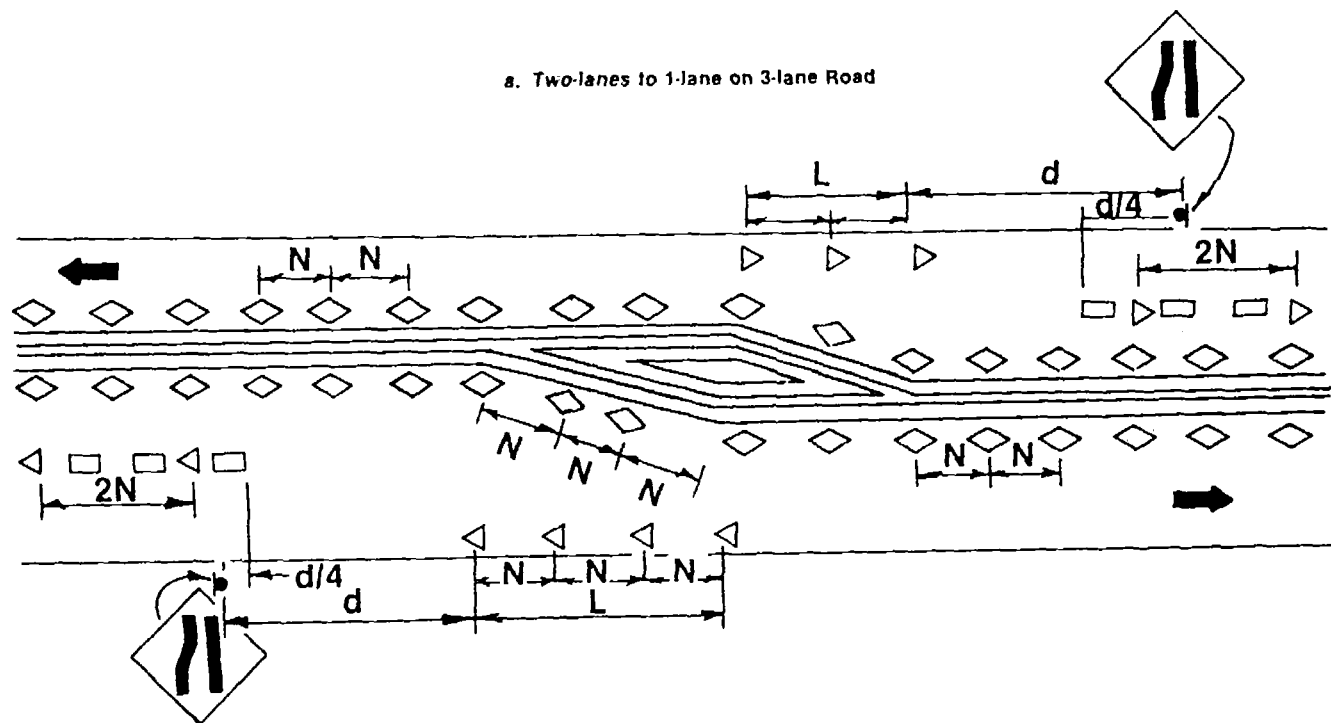


Figure 3-25 Marking Patterns for Transition Sections

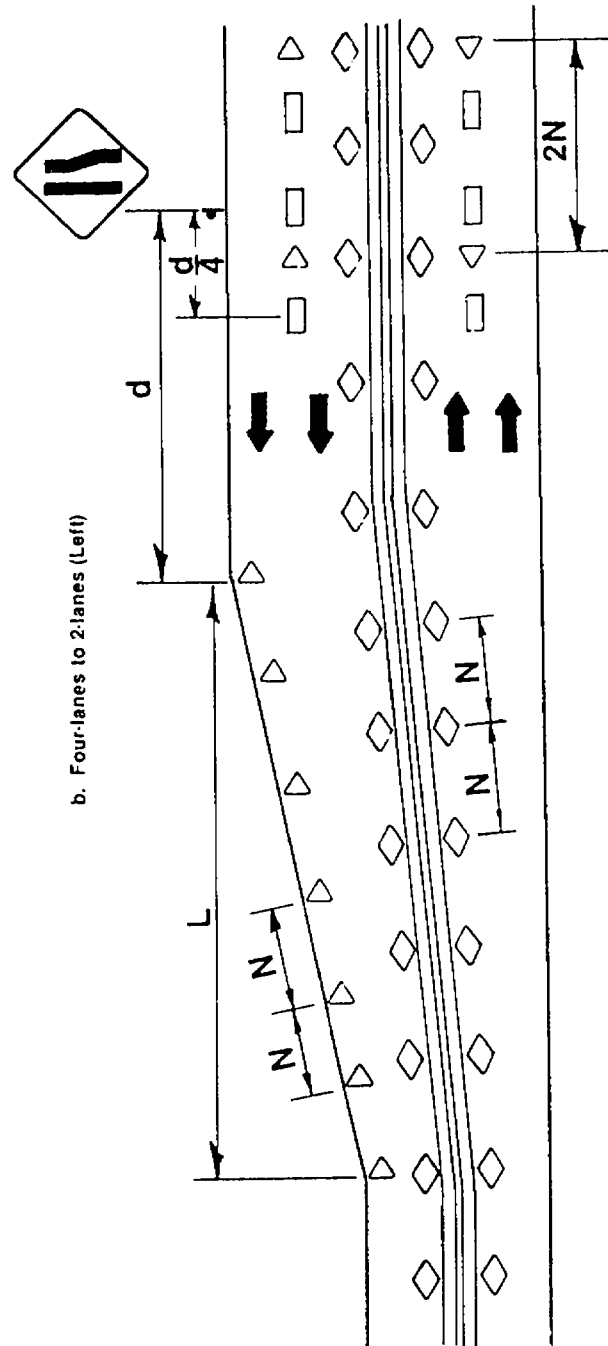


Figure 3-25 Marking Patterns for Transition Section (Con't)

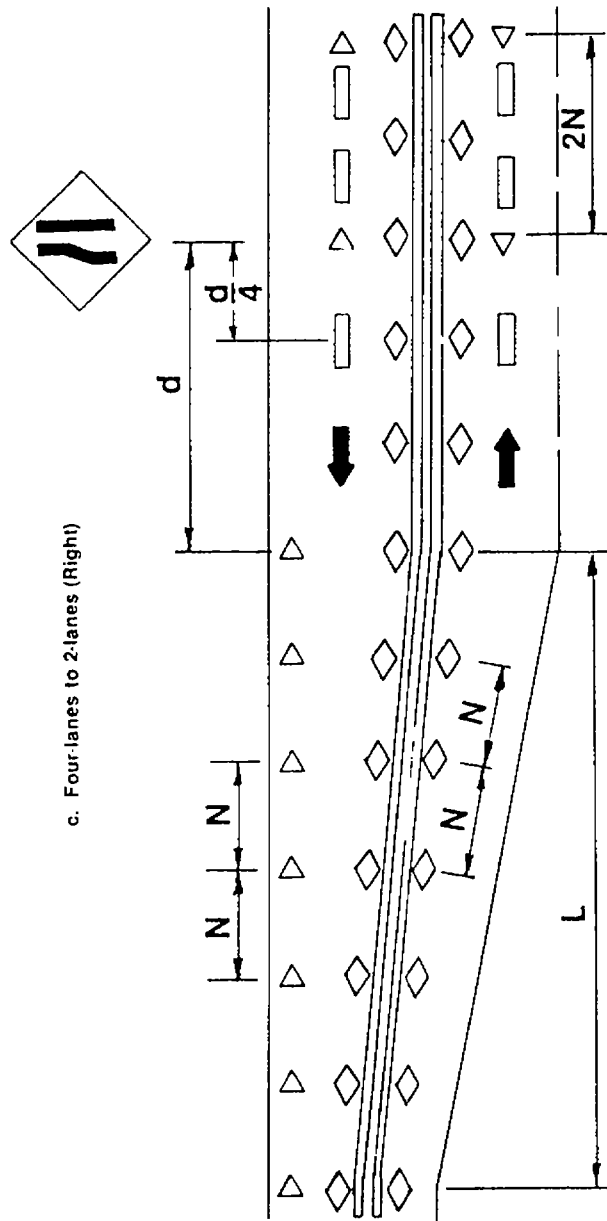


Figure 3-25 Marking Patterns for Transition Section (Con't)

a. Four lanes, 2-way Road

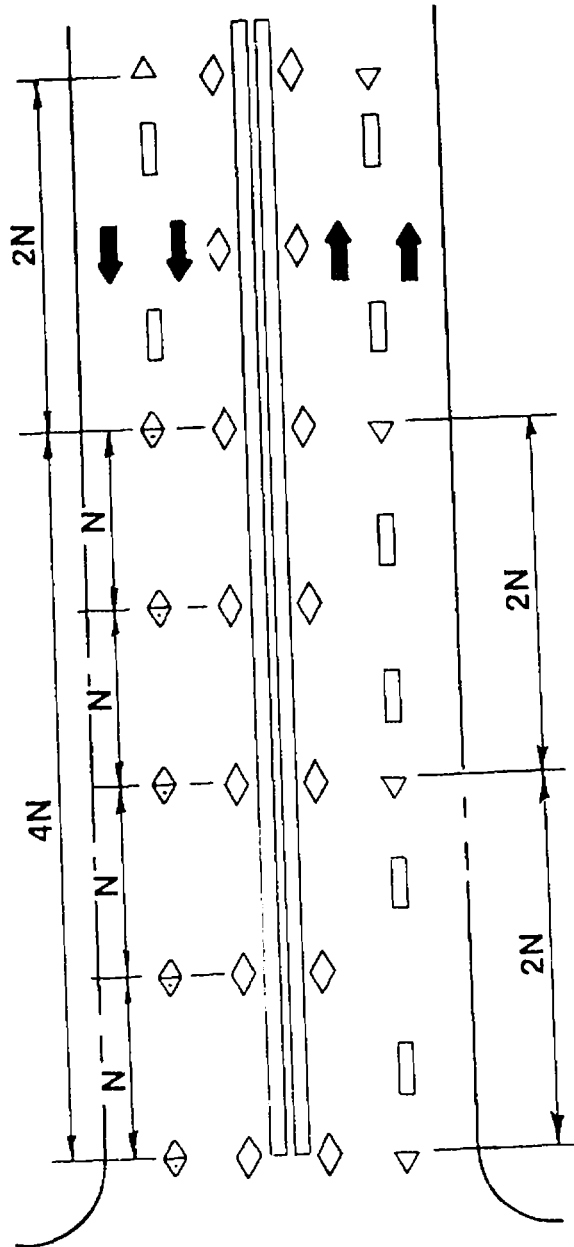


Figure 3-26 Marking Patterns for Intersection Approaches

The diagram shows a vertical chain of particles between two horizontal boundaries. The particles are represented by diamonds and rectangles. The forces and displacements are indicated as follows:

- Top boundary:** A horizontal line with a downward arrow labeled  $2N$ .
- Second particle (diamond):** A downward arrow labeled  $N$  and an upward arrow labeled  $N$ .
- Third particle (rectangle):** A downward arrow labeled  $N$  and an upward arrow labeled  $N$ .
- Fourth particle (diamond):** A downward arrow labeled  $N$  and an upward arrow labeled  $N$ .
- Fifth particle (rectangle):** A downward arrow labeled  $N$  and an upward arrow labeled  $N$ .
- Sixth particle (diamond):** A downward arrow labeled  $N$  and an upward arrow labeled  $N$ .
- Bottom boundary:** A horizontal line with an upward arrow labeled  $4N$ .

**Figure 3-26 Marking Patterns for Intersection Approaches (Con't)**

c. Two-lane, 1-Way Road

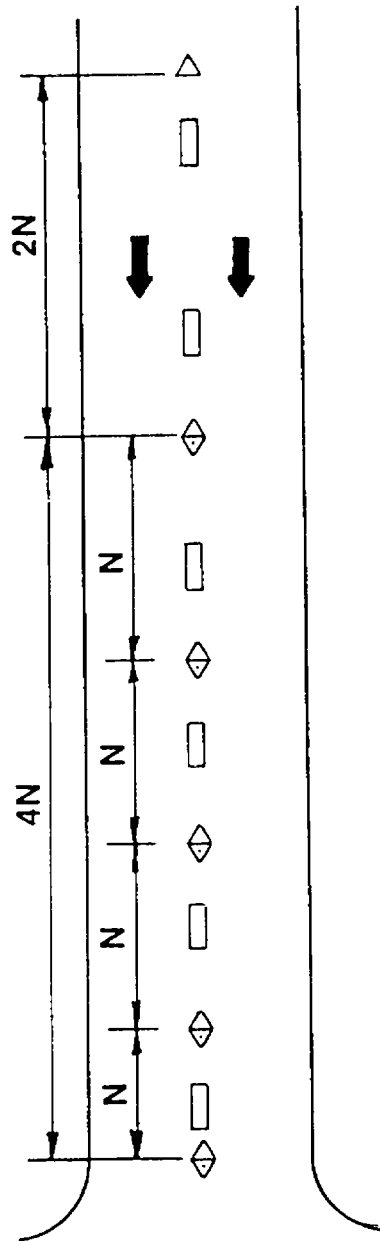


Figure 3-26 Marking Patterns for Intersection Approaches (Con't)

a. Two lanes, 2-Way Road

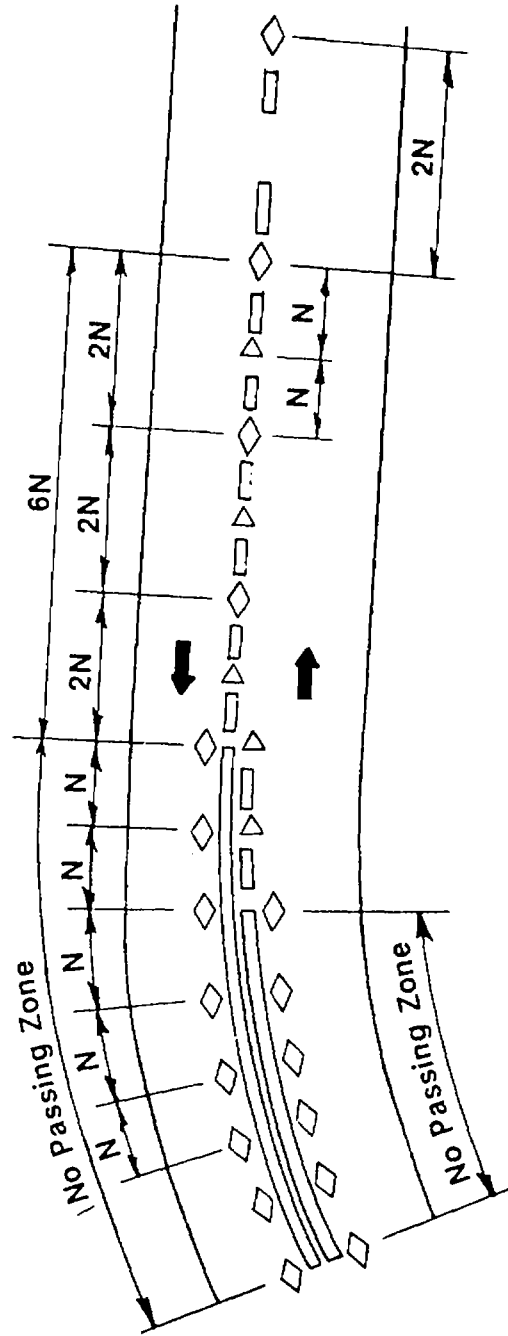


Figure 3-27 Marking Patterns for Horizontal Curves Having 6 degrees or Greater Curvature

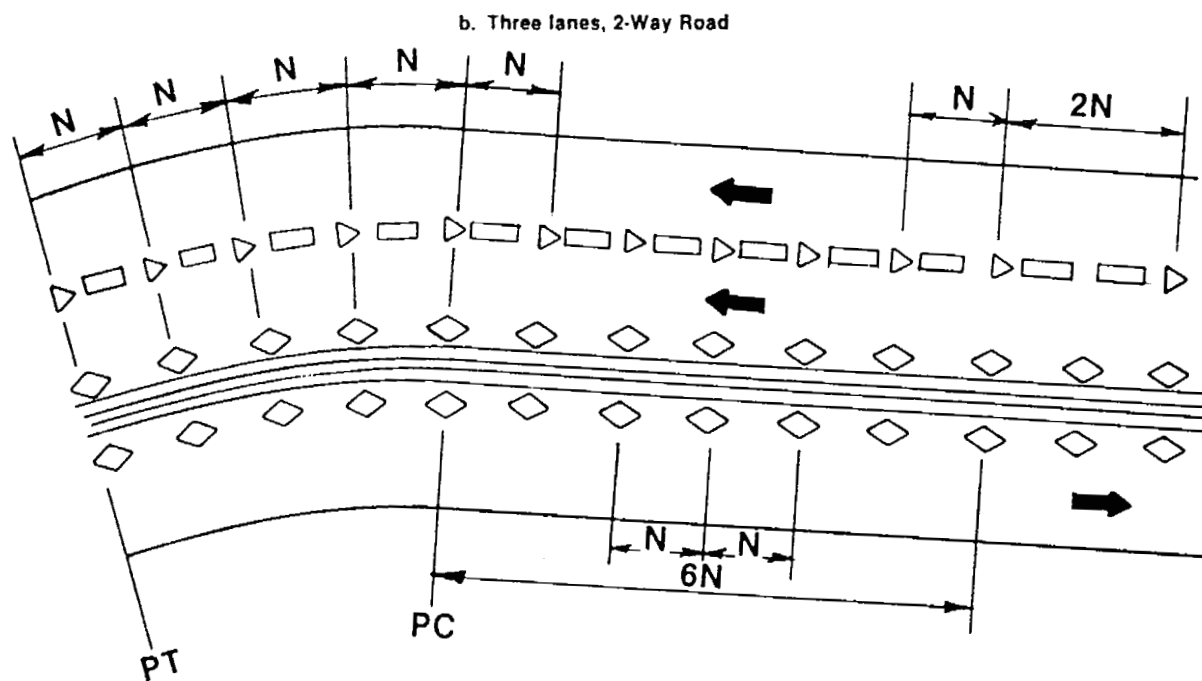


Figure 3-27 Marking Patterns for Horizontal Curves Having 6 degrees or Greater Curvature (Con't)

c. Four lanes, 2-Way Road

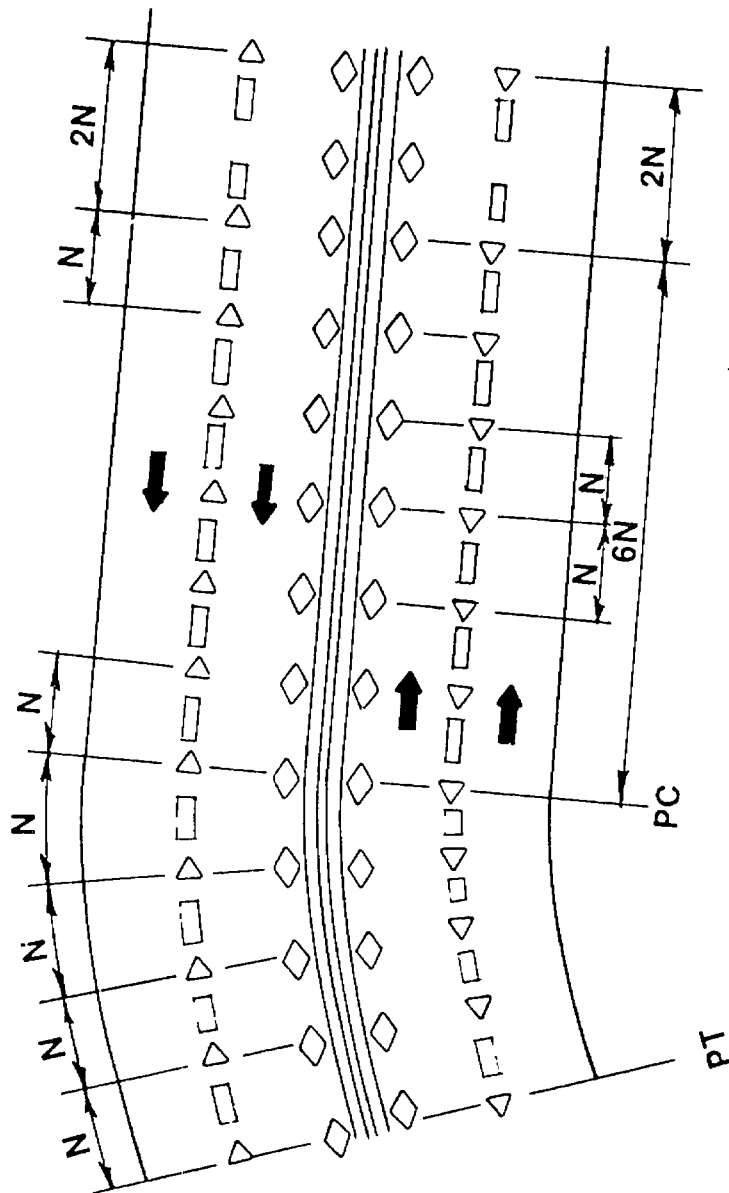


Figure 3-27 Marking Patterns for Horizontal Curves Having 6 degrees or Greater Curvature (Con't)

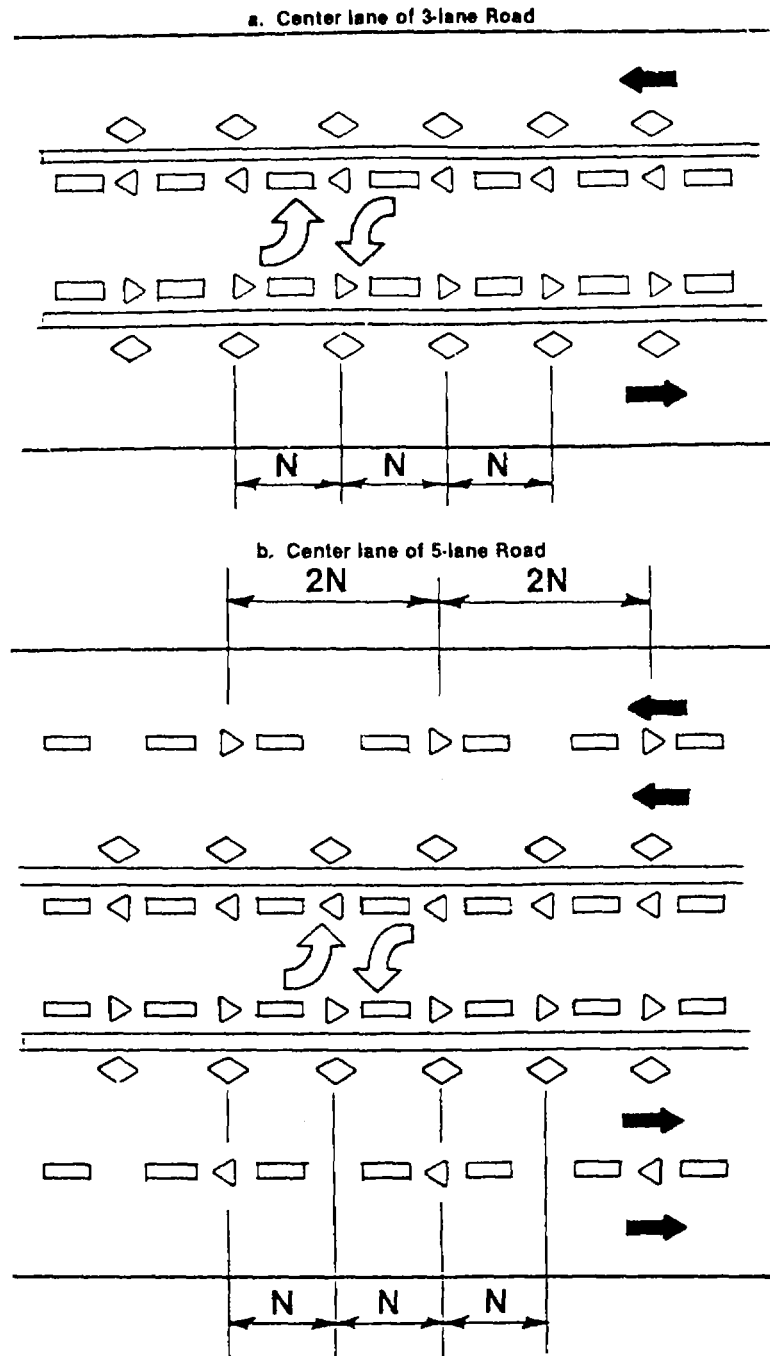


Figure 3-28 Marking Patterns for Left-Turn Lanes

c. Left-Turn Bay

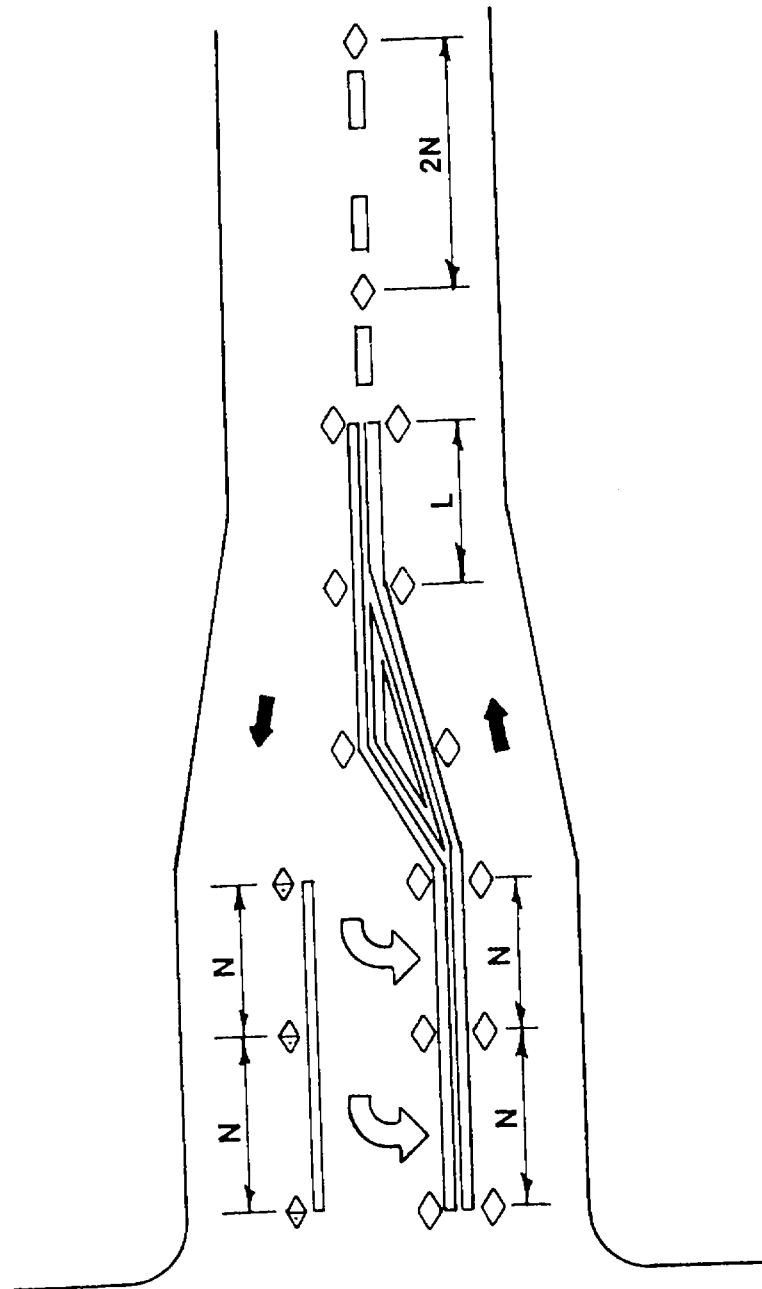
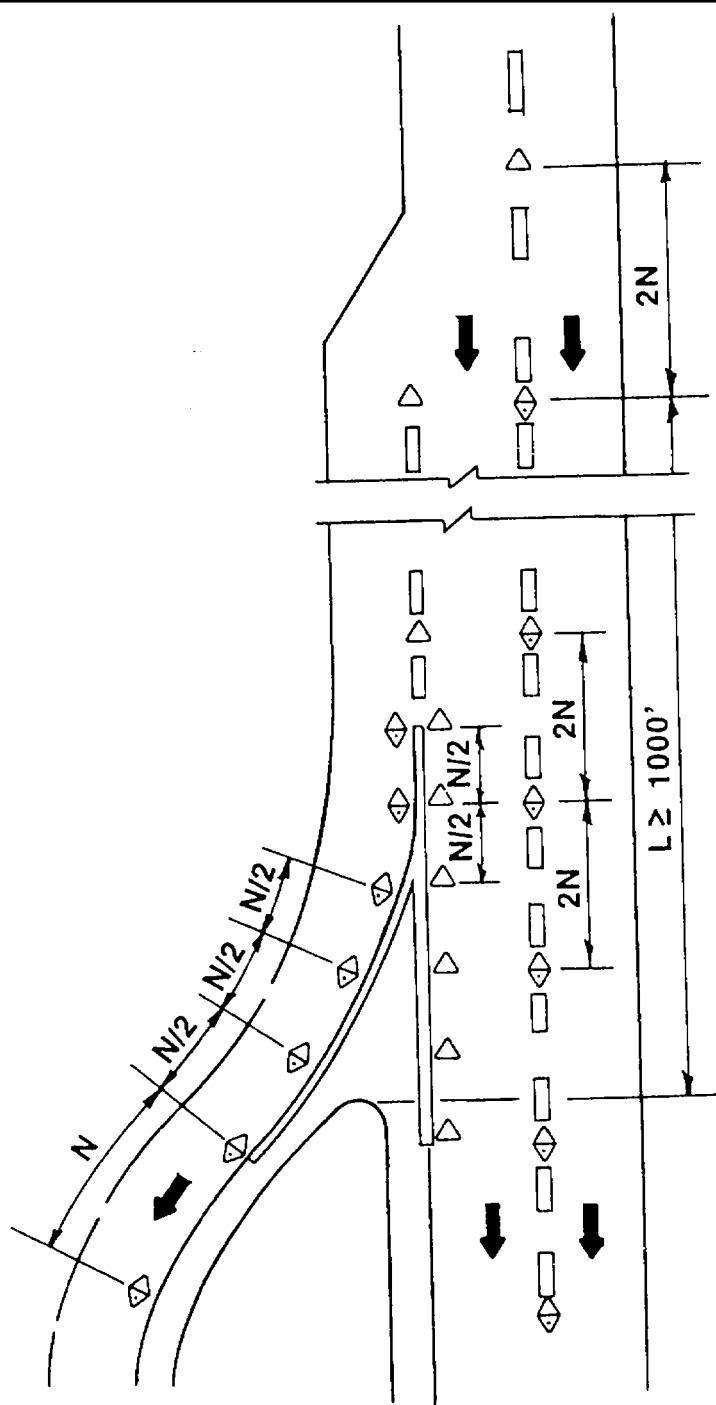


Figure 3-28 Marking Patterns for Left-Turn Lanes (Con't)



**Figure 3-29 Marking Patterns for Freeway Ramps**

b. Combination RPM/Strip System (Entrance Ramp)

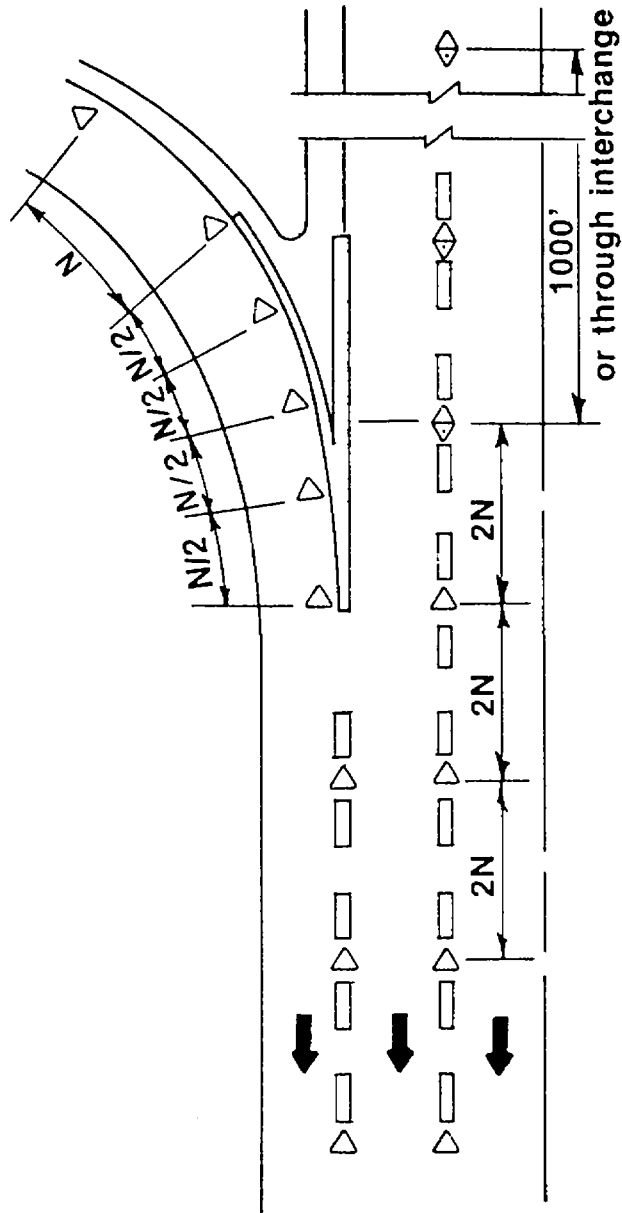
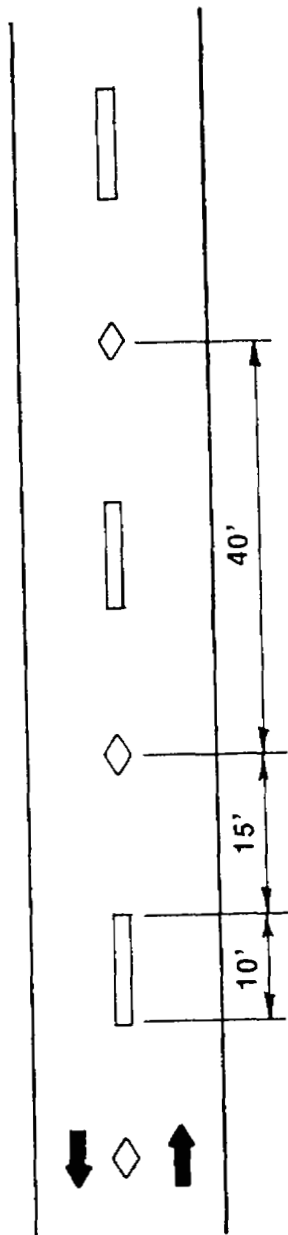


Figure 3-29 Marking Patterns for Freeway Ramps (Con't)

a. Combination RPM/Stripe System Centerline



b. Combination RPM/Stripe System Lane Line

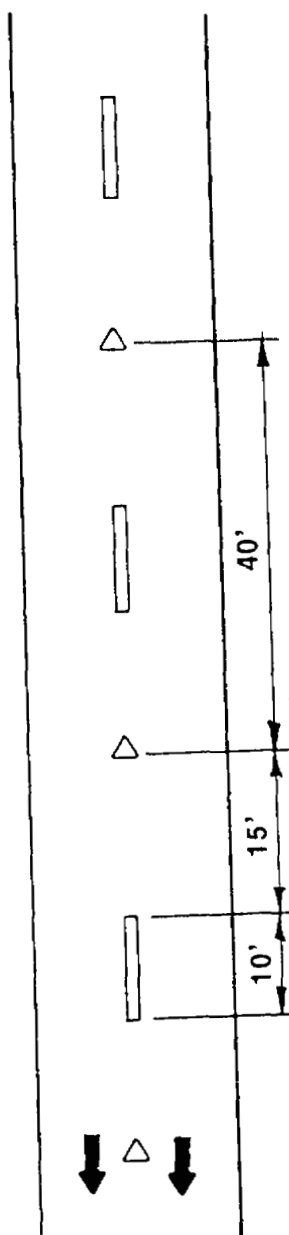
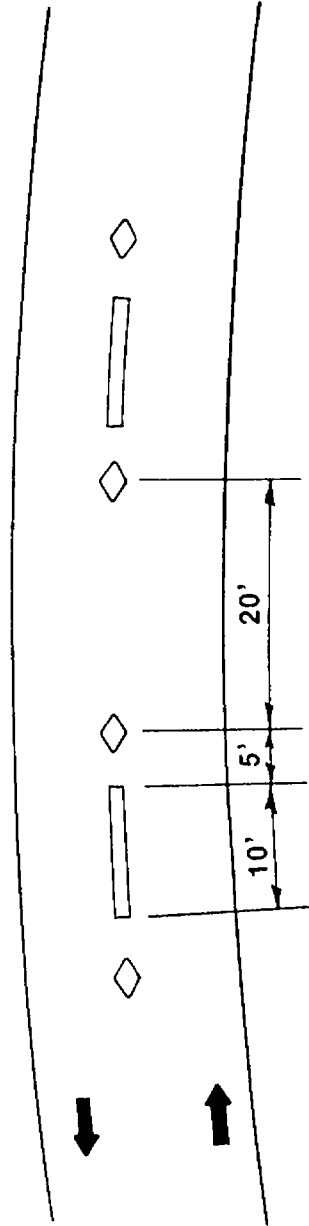
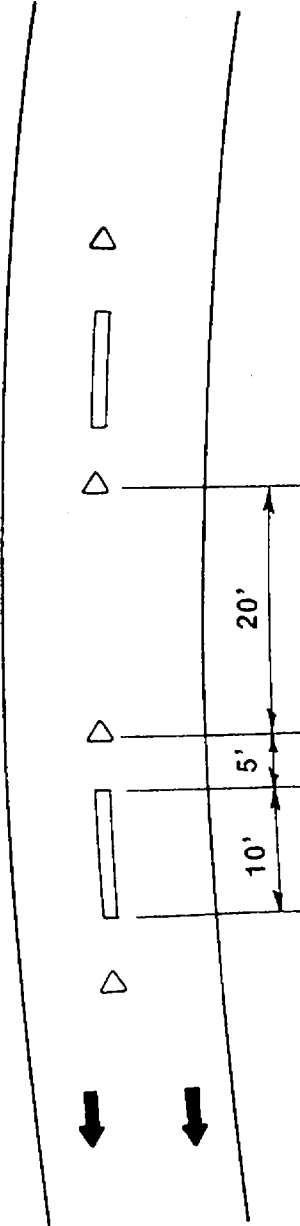


Figure 3-30 Marking Patterns for Construction Zones

c. RPM Lane Line with Stripe Edgelines



d. Combination RPM/Stripe Centerline System (Curve Section). Note: No-Passing Zones Markings are not Shown





**APPENDIX D**

***SURVEY LETTER***

August 30, 1988

Mr./Ms. John/Jane Doe  
Director, Traffic Engr. Div.  
Address  
AnyState, U.S.A.

Dear Mr./Ms. Doe,

The Arizona Department of Transportation has asked the Center for Advanced Research in Transportation at Arizona State University to prepare a state-of-the-art report on current practice and experiences with various spacings of raised reflective pavement markers (RRPM's).

Your assistance in providing your agency's experience would be of great assistance to this study. Would you send any information, manuals, criteria, data you may have on current practices and/or policies used for various spacings of raised reflective pavement markers and their effect on visibility of the striping? A list of specific conditions is attached for your convenience.

Any assistance you can provide will be greatly appreciated.

Sincerely,

J.S. Matthias, PE  
Project Manager

Enclosure  
JSM/pw  
MATT0580

Please indicate how (or if) RRPM's are used for the listed conditions for both urban and rural conditions. Please specify spacing. Any drawings would be especially helpful.

- 1) Curved sections
- 2) Tangent sections
- 3) No Passing Zones
- 4) Passing Zones
- 5) Divided Roadways
- 6) Two-way median turn lanes
- 7) Intersections
- 8) Exit and Entrance ramps